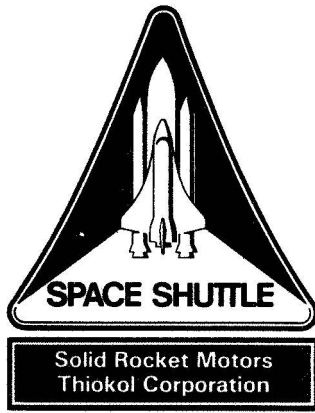


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TWR-60036

VULCANIZED REPAIR OF ASBESTOS NBR INSULATION

FINAL REPORT

OCTOBER 1990

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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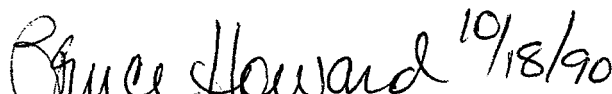

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1.0 INTRODUCTION

Occurrences of thin insulation, inclusions, defects within the insulation (interlaminar) or defects at the insulation-to-case interface have dictated washout of segment insulation periodically during the SRM and RSRM programs. Previous testing was conducted in the "NBR Rubber Secondary Vulcanization Evaluation Testing" (reported in TWR-50288) which evaluated adding uncured calendared NBR insulation over cured NBR insulation.

The testing discussed in this report was conducted per WTP-0236, "Vulcanized Repair of Asbestos NBR Insulation." The tests outlined in WTP-0236 evaluate various surface preparation materials and methods by applying a layer of uncured calendared rubber to the following three surfaces:

1. Existing cured insulation with a patterned surface (used for repair of thin insulation acreage regions).
2. Existing cured insulation with a partial layer of the cured insulation removed (simulating repair interlaminar voids).
3. Existing insulation with complete removal of insulation to the case wall (both to the Chemlok layer and to the bare metal).

2.0 OBJECTIVES

To evaluate vulcanizing raw calendared NBR to the following cured NBR surfaces:

1. Insulation with a patterned surface.
2. Insulation with a partial layer of cured material removed.
3. Insulation with a complete removal of material to the case wall (both to the Chemlok layer and to the bare metal.)

Assess the influence of the following:

1. Cleaning the surface with MEK and with TCA.
2. Abrading the surface before solvent cleanup.
3. Using a wire brush during the solvent cleaning operation.
4. Applying different Chemlok adhesive systems or tackifier as a bonding aid.

3.0 SUMMARY

The Phase I test matrix (Table I) consisted of testing (as outlined in the Objective Section) in the Development Lab on witness panels.

Using witness panels enables the tensile buttons to be vulcanized to the NBR layer rather than secondarily bonded. This produces a better bond to the button, preventing adhesive failure at the button bondline. This testing produced 100 percent cohesive failure in the NBR; no bond failure was observed at the vulcanized repair bondline.

Results from the lab testing (individual and average values are provided as Table II and an overview comparison table is provided as Table III) indicate that the Chemlok 233 system, as currently used in the aft dome to vulcanize raw NBR insulation to cured NBR insulation, provides the best bond of the tested surface mediums. Resulting bonds, after cleaning the cured insulation surfaces with MEK or TCA, are very similar. MEK, however, produced slightly higher tensile values. Use of a wire brush or abrading the cured insulation surface during the surface cleaning operation tends to slightly increase the test value strengths.

After evaluating the results from the Phase I testing, the Phase II "Full-Scale Evaluation, Test Matrix" was revised. The revised test matrix is provided in Table IV.

The samples were prepared to evaluate the following:

- Sample No. 1 - Surface repairs
- Sample No. 2 - Interlaminar repairs
- Sample No. 3 - A repair to the case wall with the Chemlok system remaining
- Sample No. 4 - A repair to the bare case wall with the Chemlok system removed

The samples were prepared following the test matrix (Table IV). After cure, tensile buttons were secondarily bonded over the patched regions with EA-934 adhesive. The buttons were then pulled by Development Lab personnel using a portable testing apparatus.

Most of the failure was determined to be at the EA-934 adhesive-to-NBR interface. Due to the failure modes observed, it is concluded that the vulcanized bondlines exceed measured strengths. The individual tensile values and failure modes from this testing are provided in Table V.

The current Chemlok 233 system is the best system to repair the surface or interlaminar defects. In addition, the tested methods of the case-to-uncured insulation repairs provide adequate bond values to consider the methods viable processes for repairing regional case-to-insulation defect areas.

4.0 CONCLUSIONS

1. Chemlok 233 provides the best bond (peel and tensile values) of all the surface mediums tested.
2. Solvent cleaning surfaces with MEK or TCA prior to vulcanization results in essentially equivalent peel values. Solvent cleaning with MEK resulted in slightly higher tensile strengths.
3. The surface preparation methods, using the wire brush (to aid in the surface cleanup) and abrasion tended to slightly increase the test strength. The increase, however, is not enough to implement the added operator technique or the additional time involved.
4. The failure modes observed on the full-scale tensile testing were at the EA-934 adhesive-to-NBR interface; therefore, it is concluded that the strength of the vulcanized repair bondline is adequate and approaches the strength on the unrepaired insulation.

5.0 RECOMMENDATIONS

It is recommended that:

1. The current method, proven and used in the aft dome to vulcanize raw NBR insulation to cured NBR insulation, be used to repair thin areas on the insulated segments when additional thickness of insulation is required. This method consists of cleaning the cured NBR with MEK, applying one coat of Chemlok 233, allowing it to dry and laying up the required raw NBR calendared material.
2. Chemlok 233 be used as the surface preparation medium for any cured NBR to raw NBR repairs and a coat of Chemlok 205 primer and a coat of Chemlok 233 be used when the repair is to the bare metal.
3. MEK continue to be used as the cleaning solvent in surface cleanup operations for vulcanized repairs.

4. Abrading of the cloth patterned surface to be repaired or using a wire brush not be conducted on vulcanized repair operations.
5. Vulcanized repair of cured NBR to raw NBR or repairs to the case wall as conducted in this testing be considered viable processes for RSRM segment internal insulation operations.

6.0 DISCUSSION

6.1 Phase I Lab Testing

NOTE

Sample Nos. 13 and 15 were fabricated to simulate interlaminar repairs, and Sample Nos. 17 and 18 were fabricated to simulate repairs to the case wall. All other samples were fabricated to simulate the pattern cloth textured surface vulcanized repairs.

SAMPLE PREPARATION

Samples were built by technicians in the M-86 Development Lab on witness panel plates. The plates were grit blasted and Chemlok 205 primer and Chemlok 233 were spray applied. Raw 0.100 inch NBR rubber was laid up on all sample panels except Samples Nos. 13 and 15 which had two 0.100 inch raw NBR rubber plies laid up. Sample No. 13 had FEP film between the two layers for easy removal of one-half of the cured insulation to provide 0.100 inch thickness and to provide a shiny surface simulating a void within the insulation. The samples were then autoclave cured.

Variables outlined in the witness panel plates test matrix (Table I) were conducted in fabricating the tensile and peel specimens. MEK and TCA were used to clean the bonding surfaces. A wire brush technique was used during the solvent cleaning operation of specific surface vulcanized repair samples. Abrading of the surface was conducted on two of the textured surface samples, all of the interlaminar repairs and all of the repairs to case wall.

Several surface enhancement mediums were also evaluated on the textured surface repairs. They were Chemlok 233 adhesive, Chemlok 236 adhesive, Chemlok 205 primer and Chemlok 233 adhesive, and an MEK base NBR tackifier. The interlaminar and case wall repairs used Chemlok 233 only, except the "case wall" sample which had the Chemlok system removed. Chemlok 205 primer and Chemlok 233 adhesive were used on this sample.

The lab testing determined the current Chemlok 233 system to be the optimum system for surface vulcanized repairs.

- a. Samples 1, 2, 7, 8, 14, and 16 were prepared using Chemlok 233. The average peel strength from these samples was 182.35 pli and the average tensile strength was 610 psi.
- b. Samples 3, 4, 9, and 10 were prepared using Chemlok 236. The average peel strength from these samples was 145.35 pli and the average tensile strength was 537 psi.
- c. Samples 5 and 11 were prepared using Chemlok 205 primer and Chemlok 233 adhesive. The average peel strength from these samples was 144.35 pli and the average tensile strength was 562 psi.
- d. Samples 6 and 12 were prepared using MEK base tackifier. The average peel strength from these samples was 140.4 pli and the average tensile strength was 522 psi.

The samples prepared using Chemlok 233 provided the best peel and tensile test values.

The tested solvents (MEK and TCA) were compared in the Chemlok 233 prepared areas.

- a. Sample 1 surface was cleaned using TCA, producing an average peel value of 181.1 pli and average tensile strength of 584 psi.
- b. Sample 2 surface was cleaned using MEK, producing average peel value of 180.9 and average tensile strength of 593 psi.
- c. Sample 7 was cleaned using TCA and a wire brush to aid in the surface cleaning, producing an average peel value of 186.5 pli and average tensile strength of 598 psi.

- d. Sample 8 was cleaned using MEK and a wire brush to aid in the surface cleaning, producing an average peel value of 180.3 pli and average tensile strength of 639 psi.
- e. Sample 14 surface area was abraded with (approximately) 80 grit cloth and then cleaned with TCA. The resulting average peel value was 178.3 pli and average tensile strength was 606 psi.
- f. Sample 16 surface area was abraded with approximately 80 grit cloth and then cleaned with MEK. The resulting average peel value was 187 pli and the average tensile strength was 642 psi.

The values produced with TCA and MEK were similar, but the MEK produced slightly higher tensile strengths. The surface preparation methods, using the wire brush to aid in the surface cleanup and abrading the surface, tended to slightly aid in the strength, but not enough to implement the added operator technique and the additional time involved.

- g. Sample No. 13 evaluated an interlaminar repair on a shiny surface formed with a layer of FEP film during initial sample preparation. The surface was abraded, cleaned with solvent, brush coated with Chemlok 233, allowed to dry, then raw insulation was laid up. The resulting average peel value was 187.5 pli and the average tensile strength was 450 psi.
- h. Sample No. 15 evaluated an interlaminar repair where a partial layer of the cured insulation had to be removed. The partial layer of insulation was removed using an air chisel. The surface was abraded, cleaned with solvent, brush coated with Chemlok 233, allowed to dry, then raw insulation was laid up. The resulting average peel value was 192.6 pli and the average tensile strength was 424 psi.
- i. Sample No. 17 evaluated insulation repaired to the witness panel Chemlok layer. The sample was prepared by brush applying a coat of Chemlok 233, allowing it to dry, and laying a layer of raw insulation. The resulting average peel value was 163.6 pli and the average tensile strength was 854 psi.

- j. Sample No. 18 evaluated insulation repaired to the steel witness panel surface. The Chemlok system was removed, a coat of Chemlok 205 primer and a coat of Chemlok 233 adhesive were brush applied, and allowed to dry, and a layer of raw insulation was laid up. The resulting average peel value was 161.0 pli and the average tensile strength was 817 psi.

Test results from the interlaminar and case wall samples provide sufficient bond strengths to implement these test methods when necessary.

6.2 Phase II Full-Scale Testing

NOTE

The witness panel values from this testing cannot be directly compared to production witness panels. These witness panels were fabricated before the final configuration of production witness panels were determined. They differ in that the cured insulation on the panels fabricated for this testing was 0.100 inch thick. The raw insulation applied for the peel specimens was 0.200 inch thick.

Production witness panel specimens of the cured NBR panels have 0.300 inch over the cured layer. The tensile buttons were fabricated with a 0.100 inch raw layer over the cured layer. Production witness panels use 0.050 inch over the cured layer.

The Phase II testing was conducted in the PSA-6 process simulation article in a region that was planned and prepared for this testing. The test matrix (Table IV) used to conduct the full-scale testing was developed by the DR Reduction Team after evaluating the test results from the Phase I testing. This test matrix evaluates:

1. Patterned surface repair.
2. Interlaminar repair.
3. Repair insulation to the case wall, leaving the Chemlok system.
4. Repair insulation to the case wall, removing the Chemlok system.

It was also decided at this time that 9-in. by 9-in. samples instead of the 12-in. by 12-in. samples were sufficient for the Phase II testing. Two test areas were prepared for each sample shown on the test matrix. The "A" samples were constructed from one lot of NBR rubber and the "B" samples were constructed with another lot of NBR rubber to determine possible effects of lot to lot rubber variation.

Pattern Surface Repair

SAMPLE PREPARATION - This testing was conducted in a region of the segment where the cured insulation was approximately 0.100-in. thick. The same process used in fabrication of the aft dome to aft barrel insulation joint on an aft segment was employed for the textured surface vulcanized insulation repair. Uncured NBR is vulcanized to previously cured NBR. The surface areas (with a patterning cloth molded surface from the previous cure) were prepared by cleaning the cured insulation surface with MEK. The MEK cleaned areas were allowed to dry 60 minutes. One coat of Chemlok 233 was applied using a foam brush and allowed to dry. One 0.100-in. thick ply of uncured NBR rubber was laid on the Chemlok coated surface of each test region.

Interlamine Repair

SAMPLE PREPARATION - This testing was conducted in an area where the cured insulation was approximately 0.200-in. thick. Approximately 0.100-in. of the cured insulation was removed using an air chisel. This method left an erratic surface. The rubber surface was abraded and cleaned with MEK. The MEK areas were allowed to dry for 60 minutes. One coat of Chemlok 233 was applied using a foam brush and allowed to dry. One layer of 0.100-in. thick ply of uncured NBR rubber was laid over the Chemlok coated surface of each test region.

Case Wall to the Chemlok System

SAMPLE PREPARATION - The insulation was removed to the case wall using an air chisel. Care was taken not to damage the cured existing Chemlok System; however, some small minor areas resulted where the bare case was exposed. The remaining surface was carefully abraded to provide a roughened surface and still leave the Chemlok system.

The repair area was cleaned with MEK and allowed to dry for 60 minutes. The few small areas where the bare metal case was exposed were spot painted with Chemlok 205 primer (foam brush applied) and allowed to dry. The entire repair region had one layer of Chemlok 233 applied by foam brush and was allowed to dry. One layer of 0.100 inch thick ply of uncured NBR rubber was laid over the Chemlok coated surface of each test region.

Case Wall Chemlok System Removed

SAMPLE PREPARATION - The insulation was removed to the case wall using an air chisel. The remaining Chemlok system was carefully abraded to expose the case wall. The repair area was cleaned with MEK and allowed to dry for 60 minutes. The bare metal of the repair region was coated using a foam brush with Chemlok 205 primer and allowed to dry. The entire repair region had one layer of Chemlok 233 applied by foam brush and was allowed to dry. One layer of 0.100 inch thick ply of uncured NBR rubber was laid over the Chemlok coated surface of each test region.

The entire segment was vacuum bagged and autoclave cured using typical aft segment cure parameters. After cure, the vacuum bag was removed from the segment and tensile adhesion buttons were secondarily bonded over the patched regions using EA-934 adhesive. The adhesive was allowed to dry 24 hours (minimum) prior to testing.

The tensile adhesion buttons were pulled by Development Lab personnel using a portable testing apparatus. Most of the failure was determined to be at the EA-934 adhesive to NBR interface. No bond failure was observed at the NBR to NBR bond interface. Based on the failure modes observed, it is concluded that the strength of the vulcanized repair bondline exceeds these values. These values reflect the strength of the EA-934 to NBR bond.

Pattern Surface Repair

Test Results - The average values for the two test areas were 513.6 psi (1A) and 463.6 psi (1B). Individual values are provided in Table V. The average tensile bond strength was 488.6 psi.

Interlaminar Repair

Test Results - The average values for the two test areas were 408.4 psi (2A) and 389.8 psi (2B). Individual values are provided in Table V. The average tensile bond strength was 399.1 psi.

Case Wall to the Chemlok System

Test Results - The average values for the two test areas were 454.5 psi (3A) and 527.3 psi (3B). Individual values are provided in Table V. The average tensile bond strength was 490.9 psi.

Case Wall Chemlok System Removed

Test Results - The average values for the two test areas were 532.3 psi (4A) and 435.5 psi (4B). Individual values are provided in Table V. The average tensile bond strength was 483.9 psi.

TABLE I. Lab Study Test Matrix

SAMPLE NO:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RUBBER LAYUP VARIATION																		
Layup .100 inch thick.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Layup .200 inch thick.													X		X			
Non-etched FEP film between the 1st and 2nd layer of calendered NBR rubber.													X					
CURED INSULATION PREPARATION																		
TCA clean with Rympie cloth.	X		X		X	X								X				
MEK clean with Rympie cloth.		X		X												X		
Wire brush & TCA clean/dry with Rympie cloth.							X		X		X	X						
Wire brush & MEK clean/dry with Rympie cloth.							X		X									
Remove layer of insulation above FEP film.													X					
Using a hand chisel, remove approximately .100 inch thickness of insulation, leaving .100 inch thickness.															X			
Abrade insulation surface with grit emery cloth.													X	X	X	X		
Using a hand chisel remove the insulation to the metal (Chemlok) surface.																	X	X
Lightly abrade the Chemlok 233 surface.																	X	
Abrade the Chemlok surface, removing the Chemlok system as well as possible.																		X
SURFACE MEDIUM																		
Brush apply 1 coat of Chemlok 233.	X	X					X	X					X	X	X	X	X	
Brush apply 1 coat of Chemlok 236.			X	X				X	X									
Brush apply 1 coat of Chemlok 205 and 1 coat of Chemlok 233.					X					X								X
One coat of MEK base tackifier						X						X						

Table II. Phase I, Test Results, Individual, Average and Failure Modes

PEEL TESTS

<u>Sample - Test No.</u>	<u>Average Stress PSI</u>	<u>Failure Mode (%)</u>		
		<u>C/A</u>	<u>C/R</u>	<u>A/R</u>
1-1	179.3	15	5	80
1-2	178.0	15	5	80
1-3	189.5	15	10	75
1-4	187.2	15	10	75
1-5	171.5	15	10	75
Avg.	181.1			
SD	7.3			
CV	4.03			
2-6	167.9	10	5	85
2-7	184.2	10	10	80
2-8	190.2	10	10	80
2-9	186.1	10	10	80
2-10	176.3	10	10	80
Avg.	180.9			
SD	8.9			
CV	4.90			
3-11	140.2	90	10	-
3-12	137.7	90	10	-
3-13	140.0	90	10	-
3-14	141.0	90	10	-
3-15	138.8	90	10	-
Avg.	139.5			
SD	1.3			
CV	0.93			
4-16	147.3	90	10	-
4-17	151.1	90	10	-
4-18	0	-	-	-
4-19	150.9	90	10	-
4-20	148.8	90	10	-
Avg.	149.5			
SD	1.8			
CV	1.21			

LEGEND:

CA = Cohesive in the adhesive (Chemlok)

CR = Cohesive in the rubber

AR = Adhesive at the rubber - Adhesive Interface

Table II. Phase I, Test Results, Individual, Average and Failure Modes (Continued)

Sample - Test No.	Average Stress PSI	Failure Mode (%)		
		C/A	C/R	A/R
5-21	149.9	20	2	78
5-22	146.6	20	2	78
5-23	148.2	20	2	78
5-24	146.9	20	2	78
5-25	137.0	20	2	78
Avg.	145.7			
SD	5.0			
CV	3.46			
6-26	148.2	-	2	98
6-27	146.3	-	2	98
6-28	148.6	-	2	98
6-29	148.6	-	2	98
6-30	152.4	-	2	98
Avg.	148.8			
SD	2.2			
CV	1.49			
7-31	193.5	15	15	70
7-32	189.7	15	15	70
7-33	190.1	15	15	70
7-34	183.1	15	15	70
7-35	176.0	15	15	70
Avg.	186.5			
SD	7.0			
CV	3.73			
8-36	175.7	10	10	80
8-37	184.7	10	10	80
8-38	184.7	10	10	80
8-39	184.3	10	10	80
8-40	172.2	10	10	80
Avg.	180.3			
SD	5.9			
CV	3.30			
9-41	149.6	100	-	-
9-42	146.7	100	-	-
9-43	149.3	100	-	-
9-44	145.3	100	-	-
9-45	132.3	100	-	-
Avg.	144.6			
SD	7.1			
CV	4.94			

LEGEND:

CA = Cohesive in the adhesive (Chemlok)
CR = Cohesive in the rubber
AR = Adhesive at the rubber - Adhesive Interface

Table II. Phase I, Test Results, Individual, Average and Failure Modes (Continued)

Sample - Test No.	Average Stress PSI	Failure Mode (%)		
		C/A	C/R	A/R
10-46	149.7	100	-	-
10-47	150.5	100	-	-
10-48	151.3	100	-	-
10-49	145.5	100	-	-
10-50	141.6	100	-	-
Avg.	147.7			
SD	4.1			
CV	2.77			
11-51	139.8	98	2	-
11-52	148.2	98	2	-
11-53	147.4	98	2	-
11-54	142.1	98	2	-
11-55	137.4	98	2	-
Avg.	143.0			
SD	4.7			
CV	3.30			
12-56	129.9	-	-	100
12-57	132.0	-	-	100
12-58	129.1	-	-	100
12-59	130.8	-	-	100
12-60	141.8	-	-	100
Avg.	132.7			
SD	5.2			
CV	3.91			
13-61	188.6	10	20	70
13-62	184.4	10	10	80
13-63	187.6	10	15	75
13-64	185.2	10	15	75
13-65	191.4	10	25	65
Avg.	187.5			
SD	3.0			
CV	1.59			
14-66	191.1	10	10	80
14-67	182.8	10	10	80
14-68	184.6	10	10	80
14-69	174.6	10	10	80
14-70	158.4	10	10	80
Avg.	178.3			
SD	12.6			
CV	7.06			

LEGEND:

CA = Cohesive in the adhesive (Chemlok)
CR = Cohesive in the rubber
AR = Adhesive at the rubber - Adhesive Interface

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**Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)**

<u>Sample - Test No.</u>	<u>Average Stress PSI</u>	<u>Failure Mode (%)</u>		
		<u>C/A</u>	<u>C/R</u>	<u>A/R</u>
15-71	184.8	10	30	60
15-72	187.1	10	30	60
15-73	205.4	10	35	55
15-74	207.3	10	40	50
15-75	178.6	10	35	55
Avg.	192.6			
SD	12.9			
CV	6.70			
16-76	177.0	30	20	50
16-77	183.8	30	20	50
16-78	191.2	30	20	50
16-79	195.0	30	20	50
16-80	189.6	30	20	50
Avg.	187.3			
SD	7.0			
CV	3.76			
17-81	157.3	-	85	15
17-82	164.5	-	85	15
17-83	164.9	-	85	15
17-84	164.6	-	85	15
17-85	166.7	-	85	15
Avg.	163.6			
SD	3.6			
CV	2.22			
18-86	154.5	-	80	20
18-87	160.4	-	80	20
18-88	164.1	-	80	20
18-89	166.0	-	80	20
18-90	160.0	-	80	20
Avg.	161.0			
SD	4.4			
CV	2.75			

LEGEND:

CA = Cohesive in the adhesive (Chemlok)
CR = Cohesive in the rubber
AR = Adhesive at the rubber - Adhesive Interface

Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)

TENSILE TESTS

Sample -	Ultimate	Failure Mode (%)			
Test No.	Stress PSI	C/A	C/R	A/R	FC
1-25	600	-	100	-	B
1-26	531	-	95	5	
1-27	598	-	100	-	
1-28	576	-	100	-	
1-29	593	-	100	-	
1-30	593	-	100	-	
1-31	577	-	100	-	
1-32	603	-	100	-	
Avg.	584				
SD	23.6				
CV	4.0				
2-33	606	-	100	-	
2-34	529	-	100	-	
2-35	617	-	100	-	
2-36	613	-	100	-	
2-37	652	-	100	-	
2-38	604	-	100	-	
2-39	608	-	100	-	
2-40	519	-	100	-	
Avg.	593				
SD	45.5				
CV	7.7				
3-41	516	-	100	-	
3-42	621	-	100	-	
3-43	578	-	100	-	
3-44	575	-	100	-	
3-45	536	-	100	-	
3-46	530	-	100	-	
3-47	549	-	100	-	
3-48	494	-	90	10	
Avg.	550				
SD	40.1				
CV	7.3				

LEGEND:

CA= COHESIVE/ADHESIVE
CR= COHESIVE/RUBBER
AR= ADHESIVE/RUBBER
FC= FAILURE COMMENT
B= BUTTON SIDE
P= PANEL SIDE

**Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)**

Sample - Test No.	Ultimate Stress PSI	Failure Mode (%)			
		<u>C/A</u>	<u>C/R</u>	<u>A/R</u>	<u>FC</u>
4-49	451	-	100	-	
4-50	446	-	100	-	
4-51	458	-	100	-	
4-52	467	-	100	-	
4-53	454	-	100	-	
4-54	473	-	100	-	
4-55	535	-	91	9	B
4-56	490	-	100	-	
Avg.	472				
SD	29.2				
CV	6.2				
5-33	581	65	30	5	
5-34	684	5	93	2	
5-35	629	10	80	10	
5-36	615	5	85	10	
5-37	513	50	35	15	
5-38	615	30	60	10	
5-39	521	45	40	15	
5-40	479	45	50	5	
Avg.	579				
SD	69.4				
CV	12.0				
6-57	535	-	100	-	
6-58	549	-	100	-	
6-59	561	-	100	-	
6-60	574	-	100	-	
6-61	544	-	100	-	
6-62	558	-	100	-	
6-63	562	-	100	-	
6-64	516	-	100	-	
Avg.	550				
SD	18.3				
CV	3.3				

LEGEND:

CA- COHESIVE/ADHESIVE
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Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)

Sample - Test No.	Ultimate Stress PSI	Failure Mode (%)			FC
		C/A	C/R	A/R	
7-73	615	-	100	-	
7-74	578	-	100	-	
7-75	611	-	100	-	
7-76	525	-	85	15	B
7-77	596	-	100	-	
7-78	623	-	100	-	
7-79	578	-	100	-	
7-80	662	-	100	-	
Avg.	598				
SD	40.1				
CV	6.7				
8-81	608	-	100	-	
8-82	637	-	100	-	
8-83	651	-	100	-	
8-84	659	-	100	-	
8-85	674	-	100	-	
8-86	595	-	100	-	
8-87	653	-	100	-	
8-88	633	-	100	-	
Avg.	639				
SD	26.4				
CV	4.1				
9-89	471	-	80	20	B
9-90	512	-	90	10	B
9-91	614	-	100	-	
9-92	601	-	100	-	
9-93	640	-	100	-	
9-94	548	-	100	-	
9-95	536	-	100	-	
9-96	562	-	100	-	
Avg.	561				
SD	55.9				
CV	10.0				

LEGEND:

CA= COHESIVE/ADHESIVE
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FC= FAILURE COMMENT
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P= PANEL SIDE

Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)

Sample - Test No.	Ultimate Stress PSI	Failure Mode (%)			FC
		C/A	C/R	A/R	
10-97	558	-	100	-	
10-98	571	-	100	-	
10-99	615	-	100	-	
10-100	540	-	100	-	
10-101	-	-	-	-	
10-102	575	-	100	-	
10-103	569	-	100	-	
10-104	510	-	100	-	
Avg.	563				
SD	32.7				
CV	5.8				
11-81	609	-	100	-	
11-82	577	-	94	6	
11-83	613	-	100	-	
11-84	523	-	90	10	
11-85	523	-	98	2	
11-86	593	-	96	4	
11-87	563	-	97	3	
11-88	555	-	98	2	
Avg.	569				
SD	35.0				
CV	6.1				
12-65	275*	-	45	55	B
12-66	571	-	100	-	
12-67	488	-	84	16	B
12-68	538	-	74	26	B
12-69	432	-	100	-	
12-70	586	-	100	-	
12-71	577	-	100	-	
12-72	484	-	100	-	
Avg.	532.7				
SD	59.5				
CV	11.4				

LEGEND:

* = Outlier, not included in calculations

CA= COHESIVE/ADHESIVE
CR= COHESIVE/RUBBER
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FC= FAILURE COMMENT
B= BUTTON SIDE
P= PANEL SIDE

**Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)**

<u>Sample - Test No.</u>	<u>Ultimate Stress PSI</u>	<u>Failure Mode (%)</u>			
		<u>C/A</u>	<u>C/R</u>	<u>A/R</u>	<u>FC</u>
13-105	512	-	40	60	P
13-106	406	-	20	80	P
13-107	432	-	20	80	P
13-108	508	-	40	60	P
13-109	511	-	40	60	P
13-110	358	-	40	60	P
13-111	353	-	25	75	P
13-112	520	-	50	50	P
Avg.	450				
SD	71.7				
CV	15.9				
14-121	598	-	100	-	
14-122	669	-	100	-	
14-123	583	-	100	-	
14-124	562	-	100	-	
14-125	460	-	90	10	P
14-126	691	-	100	-	
14-127	632	-	90	10	
14-128	653	-	100	-	
Avg.	606				
SD	73.5				
CV	12.1				
15-113	404	-	70	30	B/P
15-114	517	-	65	35	B/P
15-115	394	-	45	55	P
15-116	427	-	45	55	P
15-117	414	-	55	45	P
15-118	398	-	55	45	P
15-119	430	-	55	45	P
15-120	406	-	65	35	P
Avg.	424				
SD	39.9				
CV	9.4				

LEGEND:

CA= COHESIVE/ADHESIVE
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FC= FAILURE COMMENT
B= BUTTON SIDE
P= PANEL SIDE

**Table II. Phase I, Test Results, Individual, Average and Failure Modes
(Continued)**

Sample - Test No.	Ultimate Stress PSI	Failure Mode (%)			FC
		<u>C/A</u>	<u>C/R</u>	<u>A/R</u>	
16-129	657	-	100	-	
16-130	699	-	100	-	
16-131	631	-	100	-	
16-132	643	-	100	-	
16-133	651	-	100	-	
16-134	639	-	100	-	
16-135	547	-	100	-	
16-136	672	-	100	-	
Avg.	642				
SD	44.1				
CV	6.9				
17-137	891	-	100	-	
17-138	813	-	100	-	
17-139	857	-	100	-	
17-140	863	-	100	-	
17-141	849	-	100	-	
17-142	847	-	100	-	
17-143	882	-	100	-	
17-144	829	-	100	-	
Avg.	854				
SD	25.5				
CV	3.0				
18-137	838	-	95	5	
18-138	792	-	95	5	
18-139	802	-	95	5	
18-140	788	-	97	3	
18-141	842	-	90	10	
18-142	846	-	93	7	
18-143	832	-	93	7	
18-144	802	-	96	4	
Avg.	817				
SD	23.9				
CV	2.9				

LEGEND:

CA- COHESIVE/ADHESIVE
CR- COHESIVE/RUBBER
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Table III. Phase I, Test Results, Overview

Sample No.	Peel Results	TCA	MEK	Wire Brush	Abrade	Tensile Results
Chemlok 233						
1	181.1	X				584
2	180.9		X			593
7	186.5	X		X		598
8	180.3		X	X		639
14	178.3	X			X	606
16	187.		X		X	642
17	163.6				X	854
(Case)						
(Interlaminar)						
13	187.5				X	450
15	187.				X	424
(Interlaminar)						
Chemlok 236						
3	139.5	X				550
4	149.5		X			472
9	144.7	X		X		561
10	147.7		X	X		563
Chemlok 205/ 233 (Case)						
5	145.7	X				561
11	143.	X		X		563
18	161.				X	817
Tackifier						
6	148.8	X				550
12	132.7	X		X		493

Table IV. Revised Phase II Test Matrix

	SAMPLE NO.			
	1	2	3	4
CURED INSULATION PREPARATION				
Using a hand chisel, remove approximately 0.100-inch thickness of insulation, leaving approximately 0.100-inch thickness		X		
Using a hand chisel, remove the insulation to the metal (Chemlok) surface			X	X
Abrade insulation surface with 80-100 grit cloth		X		
Lightly abrade the Chemlok 233 surface			X	
Abrade the Chemlok surface, removing the Chemlok system as well as possible				X
MEK clean with Rympcloth	X	X	X	X
SURFACE MEDIUM				
Brush apply one coat of Chemlok 233	X	X	X	
Brush apply one coat of Chemlok 205 and one coat of Chemlok 233				X

**Table V. Full-Scale Test Article Surface Vulcanization Repair
Pattern Surface Repair**

TENSILE VALUES					
		Failure Mode (%)			
Ultimate Stress					
Test No.	(psi)	AMF	AIF	HI	HA
1A-1	334*	95		1	4
1A-2	594		75	25	
1A-3	561		70	30	
1A-4	457		90	10	
1A-5	443		90	10	
Avg	513.6				
SD	75.0				
CV	14.6%				

		Failure Mode (%)			
Ultimate Stress					
Test No.	(psi)	AMF	AIF	HI	HA
1B-1	412	99			1
1B-2	556		90	10	
1B-3	189*	95	4 (1% VOID)		
1B-4	406		85	15	
1B-5	481		90	10	
Avg	463.6				
SD	70.4				
CV	15.2%				

* Considered an outlier- Not used in these calculations

LEGEND:

AMF= Adhesive/Metal Interface
AIF= Adhesive/Insulation Interface
HI= Cohesive/ Insulation
HA= Cohesive/ Adhesive

Table V. Full-Scale Test Article Surface Vulcanization Repair (Continued)

		Interlaminar Repair Failure Mode (%)			
Test No.	Ultimate Stress (psi)	AMF	AIF	HI	HA
2A-6	357		50	45	5% VOID
2A-7	442		50	50	
2A-8	413		45	45	10% VOID
2A-9	411		50	50	
2A-10	420		50	50	
Avg	408.4				
SD	31.2				
CV	7.6%				

		Failure Mode (%)			
Test No.	Ultimate Stress (psi)	AMF	AIF	HI	HA
2B-6	426		50	50	
2B-7	408		45	45	10% VOID
2B-8	397	40	20	20	20% VOID
2B-9	309		35	30	35% VOID
2B-10	409		50	45	5% VOID
Avg	389.8				
SD	46.1				
CV	11.8%				

		Case Wall Chemlok System Removed Failure Mode (%)			
Test No.	Ultimate Stress (psi)	AMF	AIF	HI	HA
3A-1	357*	95		1	4
3A-2	453		95	5	
3A-3	437		95	5	
3A-4	492		95	5	
3A-5	534		85	15	
Avg	454.5				
SD	66.3				
CV	14.6%				

LEGEND:

AMF= Adhesive/Metal Interface

AIF= Adhesive/Insulation Interface

HI= Cohesive/ Insulation

HA= Cohesive/ Adhesive

* Considered an outlier- Not used in these calculations

Table V. Full-Scale Test Article Surface Vulcanization Repair (Continued)

		Failure Mode (%)			
Ultimate Stress					
Test No.	(psi)	AMF	AIF	HI	HA
3B-1	438		70	28	2% VOID
3B-2	550		50	50	
3B-3	464		44	44	12% VOID
3B-4	508	85	10	5	
3B-5	676		30	70	
Avg	527.3				
SD	93.3				
CV	17.7%				

		Case Wall Chemlok System Removed Failure Mode (%)			
Ultimate Stress					
Test No.	(psi)	AMF	AIF	HI	HA
4A-6	540		40	60	
4A-7	509		40	60	
4A-8	582		40	60	
4A-9	488	60	20	20	
4A-10	543	10	40	50	
Avg	532.3				
SD	36.0				
CV	6.8%				

		Failure Mode (%)			
Ultimate Stress					
Test No.	(psi)	AMF	AIF	HI	HA
4B-6	468		50	50	
4B-7	374		35	35	30% VOID
4B-8	466	60	20	20	
4B-9	530		35	65	
4B-10	340		35	35	30% VOID
Avg	435.5				
SD	77.4				
CV	17.8%				

LEGEND:

AMF= Adhesive/Metal Interface
AIF= Adhesive/Insulation Interface
HI= Cohesive/ Insulation
HA= Cohesive/ Adhesive

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